United States Marine Corps
Command and Staff College
Marine Corps University
2076 South Street
Marine Corps Combat Development Command
Quantico, Virginia 22134-5068

MARINE AIR GROUND TASK FORCE (MAGTF) EXPEDITIONARY FAMILY OF FIGHTING VEHICLES (MEFFV) -- RECONNAISSANCE VARIANT; CONCEPT DEVELOPMENT VALIDATING OPERATIONAL MANEUVER CAPABILITIES AS A MARINE CORPS 1ST ECHELON REQUIREMENT IN 2020

by

Major John M. Reed, USMC

A thesis submitted in partial fulfillment of the requirements for the degree of

Masters of Military Studies

Marine Corps University

AY 2001-2002

Mentor: Norman Cigar, D. Phil.
Approved:
Date:

Mentor: Kenneth Gaskill, LtCol, USMC
Approved:
Date:

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (FROM - TO)
05-05-2002	Student research paper	xx-xx-2001 to xx-xx-2002

4. TITLE AND SUBTITLE
Marine Air Ground Task Force (MAGTF) Expeditionary Family of Fighting Vehicles (MEFFV)--Reconnaissance Variant; Concept Development Validating Operational Maneuver Capabilities as a Marine Corps 1st Echelon Requirement in 2020
Unclassified

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Reed, John M. ;

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME AND ADDRESS
USMC Command and Staff College
2076 South Street
MCCDC
Quantico, VA22134-5068

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME AND ADDRESS
USMC Command and Staff College
2076 South Street
MCCDC
Quantico, VA22134-5068

10. SPONSOR/MONITOR'S ACRONYM(S)
11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
APUBLIC RELEASE
,

13. SUPPLEMENTARY NOTES

14. ABSTRACT
See report.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE	Public Release	58	EM114, (blank) lfenster@dtic.mil
Unclassified	Unclassified	Unclassified			19b. TELEPHONE NUMBER International Area Code Area Code Telephone Number 703767-9007 DSN 427-9007

REPORT DOCUMENTATION PAGE

FORM APPROVED - - - OMB NO. 0704-0188

1. AGENCY USE ONLY (*LEAVE BLANK)*	2. REPORT DATE 5 MAY 2002	3. REPORT TYPE AND DATES COVERED ***STUDENT RESEARCH PAPER***

4. TITLE AND SUBTITLE MARINE AIR GROUND TASK FORCE (MAGTF) EXPEDITIONARY FAMILY OF FIGHTING VEHICLES (MEFFV) - - RECONNAISSANCE VARIANT; CONCEPT DEVELOPMENT VALIDATING OPERATIONAL MANEUVER CAPABILITIES AS A MARINE CORPS 1ST ECHELON REQUIREMENT IN 2020	5. FUNDING NUMBERS ***N/A***
6. AUTHOR(S) MAJOR JOHN M. REED, USMC	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) ***USMC COMMAND AND STAFF COLLEGE*** ***2076 SOUTH STREET, MCCDC, QUANTICO, VA 22134-5068***	8. PERFORMING ORGANIZATION REPORT NUMBER ***NONE***
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) ***SAME AS #7.***	10. SPONSORING/MONITORING AGENCY REPORT NUMBER: ***NONE***
11. SUPPLEMENTARY NOTES ***NONE***	
12A. DISTRIBUTION/AVAILABILITY STATEMENT ***NO RESTRICTIONS***	12B. DISTRIBUTION CODE ***N/A***

13. ABSTRACT: THIS PAPER ANALYZES AND PROJECTS THE CAPABILITIES REQUIRED BY FUTURE JOINT FORCE COMMANDERS IN ORDER TO CONSISTENTLY ASSIGN OPERATIONAL OBJECTIVES TO A GROUND COMBAT ELEMENT OF A MAGTF. AS AN INITIAL INDEPENDENT STUDY SUPPORTING THE CONCEPT DEVELOPMENT, THIS PAPER IDENTIFIES CONCRETE CAPABILITIES FOR THE MEFFV RECONNAISSANCE VARIANT, ORIENTED ON OPERATIONAL MANEUVER CAPABILITIES AS A MARINE CORPS 1ST ECHELON REQUIREMENT IN 2020. AS A NAVAL EXPEDITIONARY FORCE ON AMPHIBIOUS ASSAULT LIFT, THE MEFFV-EQUIPPED UNIT REQUIRES OPERATIONAL MOBILITY IN ORDER TO AVOID ENEMY COUNTER MANEUVERS; IT MUST HAVE THE CAPABILITY OF MOVING SIGNIFICANT DISTANCES, MAINTAINING ORGANIC COMBAT POWER, MAXIMIZING INTEROPERABILITY WITH JOINT SYSTEMS, AND REMAINING INDEPENDENT OF GROUND LOGISTICAL LINES. THE MEFFV UNIT MUST BE MULTI-MISSION CAPABLE ACROSS THE SPECTRUM OF CONFLICT AS A COMBINED ARMS FORCE. THE TECHNOLOGIES NECESSARY FOR MEFFV EXIST TOADY IN MID-RANGE READINESS LEVELS. IDENTIFYING THE CAPABILITIES REQUIRED TO FOCUS THE ORIENTATION OF RESEARCH AND DEVELOPMENT FUNDING IS IMPORTANT NOW. WITH MEFFV-EQUIPPED UNITS, THE JOINT FORCE COMMANDER OF 2020 COULD CONFIDENTLY CONDUCT OPERATIONAL MANEUVER AS THE MILITARY MEANS TO SUPPORT OTHER ELEMENTS OF NATIONAL POWER IN ORDER TO ACHIEVE POLITICAL GOALS MORE EFFICIENTLY.

14. SUBJECT TERMS (KEY WORDS ON WHICH TO PERFORM SEARCH) MEFFV, OPERATIONAL MANEUVER	15. NUMBER OF PAGES: 47
	16. PRICE CODE: N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE:	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT 200 WORDS
UNCLASSIFIED	***UNCLASSIFIED***	***UNCLASSIFIED***	

DISCLAIMER

THE OPINIONS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF THE U.S. MARINE CORPS, THE MARINE CORPS COMMAND AND STAFF COLLEGE OR ANY OTHER GOVERNMENTAL AGENCY. REFERENCES TO THIS STUDY SHOULD INCLUDE THE FOREGOING STATEMENT.

EXECUTIVE SUMMARY

Title: Marine Air Ground Task Force (MAGTF) Expeditionary Family of Fighting Vehicles (MEFFV) - - Reconnaissance Variant; Concept Development Validating Operational Maneuver Capabilities as a Marine Corps 1st Echelon Requirement in 2020

Author: Major John M. Reed, USMC

Thesis: This paper argues that Marines will be consistently capable of operational maneuver if equipped with the MEFFV, a vehicle system of improved capabilities.

Discussion.

This paper analyzes and projects the capabilities required by future Joint Force Commanders in order to consistently assign operational objectives to a ground combat element of a MAGTF. The MEFFV program is in the early stage of concept development. It is significant to the Marine Corps, as it replaces current vehicle systems that will not only reach the end of their service life but also fail to have significant advantages on the future battlefield against forecasted threats. To place this paper in context, it is the first attempt to validate the MEFFV program in relation to capabilities-based requirements for operational maneuver.

As an initial independent study supporting the concept development, this paper identifies concrete capabilities for the Reconnaissance Variant, oriented on operational maneuver capabilities as a Marine Corps 1st echelon requirement in 2020. As a naval expeditionary force on amphibious assault lift, the MEFFV-equipped unit requires operational mobility in order to avoid enemy counter maneuvers; it must have the capability of moving significant distances, maintaining organic combat power, maximizing interoperability with joint systems, and remaining independent of ground logistical lines. The MEFFV unit must be multi-mission capable across the spectrum of conflict as a combined arms force. Possible mission role variant modules that could be plugged into the common reconnaissance vehicle hull are the assault gun; armored personnel carrier; reconnaissance; command, control, communications, computers, information, surveillance, and reconnaissance (C4ISR); indirect fires; engineer; air defense; logistics; ambulance; and maintenance.

The technologies necessary for MEFFV exist toady in mid-range readiness levels. Identifying the capabilities required to focus the orientation of research and development funding is important now. With MEFFV-equipped units, the Joint Force Commander of 2020 could confidently conduct operational maneuver as the military means to support other elements of national power in order to achieve political goals more efficiently.

TABLE OF CONTENTS

LIST OF FIGURES

Chapter 1

MEFFV

INTRODUCTION

This paper will analyze and project the capabilities required by future Joint Force Commanders in order to consistently assign operational objectives to a ground combat element of a Marine Air Ground Task Force (MAGTF). My thesis is that Marines will be consistently capable of operational maneuver if equipped with the MAGTF Expeditionary Family of Fighting Vehicles (MEFFV), a vehicle system of improved capabilities. In many global situations involving aspects of the entire spectrum of war, in fact, this capability has the potential to change the equilibrium in asymmetric conflicts in the favor of U.S. forces operating unilaterally or in multinational operations.

This paper will include the conceptual framework for understanding the link between the human element in war, creating tempo with operational maneuver, and how improved equipment capabilities will enhance the abilities of a 1st echelon MAGTF maneuver element. The paper will also explore current doctrine and link it to the technological requirements to create an improved capability of MEFFV-equipped units. The technology approach of the MEFFV program will be included in order to shape the direction of the capabilities-based requirements. The paper will then define the capabilities to be pursued by technology investment priorities within the context of the warfighting functions. Central to the paper's focus is the linkage of technological improvements to non-material changes such as doctrinal

innovation and organizational adaptation. The non-material changes, historically the Marine Corps' forte, must be enhanced by the orientation of MEFFV technological advances.

The MEFFV program is in the early stage of concept development. It is significant to the Marine Corps, as it replaces current vehicle systems that will not only reach the end of their service life but also fail to have significant advantages on the future battlefield against forecasted threats. To place this paper in context, this is the first attempt to validate the MEFFV program in relation to capabilities-based requirements for operational maneuver.

I have the benefit of personal experience in the Light Armored Vehicle community during the experimentation with deep maneuver in 1996 and 1997. The Deep Strike series of experiments and exercises documented innovative approaches to tactics, techniques, and procedures to achieve operational effects of a force capable of maneuvering deep. The Operational Working Group, which was responsible for the Deep Strike experiments, for its part identified shortfalls in equipment capabilities currently fielded. This personal experience has been particularly useful to me in understanding the operational and "real-world" factors, as well as conceptual issues, related to this topic.

STATEMENT OF THE PROBLEM

The MEFFV is in the early stages of concept development. As an initial independent study supporting the concept development, this paper will identify concrete capabilities for the Reconnaissance Variant, validating Operational Maneuver capabilities as a Marine Corps 1st echelon requirement in 2020. Although, the focus is primarily on the capabilities required for the MEFFV Reconnaissance Variant, portions of the capabilities findings will apply to the

Assault Variant as well. For the U.S., technology investments to procure weapon systems by defense industries have a Research and Development (R&D) cycle of ten to fifteen years.[1] This time lag from fielding to development makes it critical to identify technology investment priorities now in order for MEFFV to meet Full Operational Capable (FOC) status in 2020. However, the possibility of fielding off-the-shelf technology will significantly affect this potential.

The technologies necessary for MEFFV exist today in mid-range readiness levels. Identifying the capabilities required to focus the orientation of Research and Development funding is important now. Four axioms are critical to the context of this work. First, what we procure in the future will be better than what we have today in the context of relative military effectiveness in the national security environment. Second, what we do now to identify future requirements will shape what is available for fielding. Third, what we procure in the future will depend on current technology readiness levels. And fourth, operators transforming doctrine, organizations, tactics, techniques, and procedures must overcome obstacles that can not be addressed by technology alone. As an introductory effort, the analysis here will develop this problem in order to contribute to the development of the Marine Corps' operational maneuver potential.

[1] Michael S. Loescher, Chris Schroeder, and Charles W. Thomas, *Proteus, Insights from 2020* (N.P.: The Copernicus Institute Press, 2000), A-ix.

MISSION NEED STATEMENT

The Assistant Commandant of the Marine Corps approved the Mission Need Statement (MNS) for the MEFFV (No. MOB 46) on 20 December 2000.[2] The requirement for this MNS emanated from a series of documents: parts I and II of the Defense Planning Guidance for Fiscal Years 2001-2005, dated April 1999; *Operational Maneuver From The Sea* (OMFTS) - *A Concept for the Projection of Naval Power Ashore*, dated 4 January 1996; *Ship To Objective Maneuver* (STOM), dated 25 July 1997; *The MAGTF in Sustained Operations Ashore*, dated 28 June 1998; the Commandant of the Marine Corps Planning Guidance dated 31 August 1997; the *Marine Corps Master Plan for the 21st Century - Required Operational Capabilities* R.4, R.15, R.16, R.19, and R.35; and the *OMFTS Implementation Study* dated 18 February 1997.[3] The MEFFV concept is for a family of vehicles to replace the Marine Corps' Light Armored Vehicle (LAV) and M1A1 Main Battle Tank as they reach their end of service life in 2015 and 2020, respectively. The MEFFV MNS seeks to not only call for the replacement of these combat vehicle systems at their end of service, but also to identify new capabilities-based requirements as the LAV and M1A1 become irrelevant against the forecasted threat of future conflicts.[4]

The mission and threat analysis used by the MEFFV MNS emerged from the concepts of the OMFTS and STOM working groups, which is the maneuver of 1st echelon naval forces at the operational level. Specifically, the landing force requires operational mobility in order to avoid enemy counter maneuvers; it must have the capability of moving significant distances,

---

[2] Commanding General, Marine Corps Combat Development Command, "Mission Need Statement Endorsement" 8 January 2001, 1; the endorsement cites the approval of the Assistant Commandant of the Marine Corps.

[3] *Mission Need Statement for MEFFV, No. MOB 46*, 2.

[4] *Mission Need Statement for MEFFV*, 2.

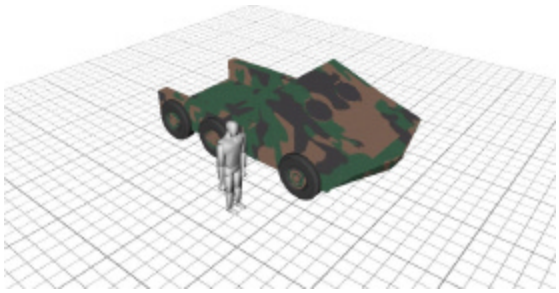
maintaining organic combat power, maximizing interoperability with joint and multinational forces, and remaining independent of ground logistical lines.[5]

THE MEFFV VARIANTS

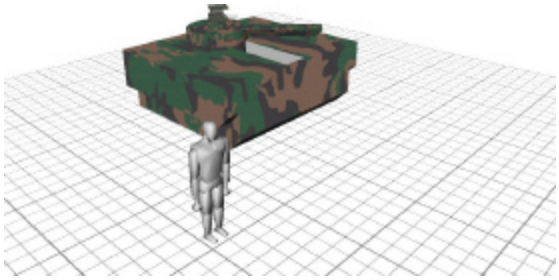
The MEFFV Program Office will develop a heavy Assault Variant and a light Reconnaissance Variant. Transportability constraints have caused the MEFFV Program Office to pursue two weight classes: thirty and ten tons. The Assault Variant has a projected maximum weight of thirty tons. This weight constraint exists so that two vehicles of this type can fit on an enhanced Landing Craft Air Cushion (LCAC). The Reconnaissance Variant will weigh approximately ten tons; four to six of this vehicle-type should fit on an LCAC. If the Reconnaissance Variant weight remains at ten tons and still meets the capabilities required, it will be externally transportable by heavy-lift helicopters. Each variant will be capable of multiple mission roles using modular systems and components. Possible mission role variant modules for the reconnaissance vehicle hull to be explored here are the assault gun; armored personnel carrier; reconnaissance; command, control, communications, computers, information, surveillance, and reconnaissance (C4ISR); indirect fires; engineer; air defense; logistics; ambulance; and maintenance. The family of variants concept was developed for the LAV family of vehicles (including the LAV-25mm, LAV-Anti-Tank, LAV-Mortar, LAV-Air Defense, LAV-C2, LAV-Logistics, and LAV-Recovery) in order to give one unit an organic, mutually supporting combined arms capability. However, the LAV variants are permanent; they are not

[5] *Mission Need Statement for MEFFV*, 1.

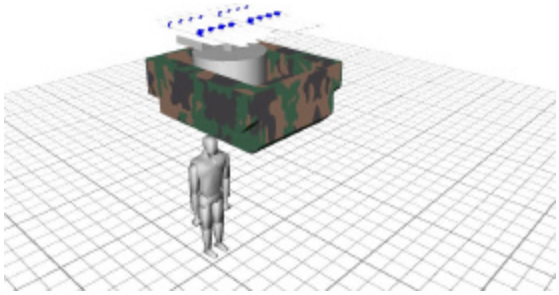
modular. Unlike the LAV, commanders will be able to task organize the MEFFV units by interchanging the modular components to meet different situations and the changing requirements of the future battlefield. The hull will be a common system, while modules with different capabilities could be dropped into the hulls to specifically meet the needs of the mission situation. For example, if an air threat did not exist and, instead, mines and obstacles were prevalent, air defense modules could be replaced by engineer modules on the same hull. The following conceptual sketches in Figure 1-1 graphically depict the modularity of MEFFV.



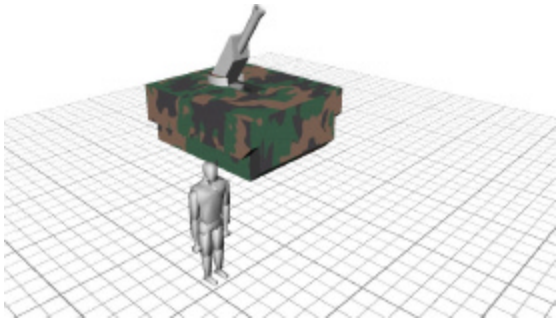
(Conceptual Sketch of Empty Common Hull)



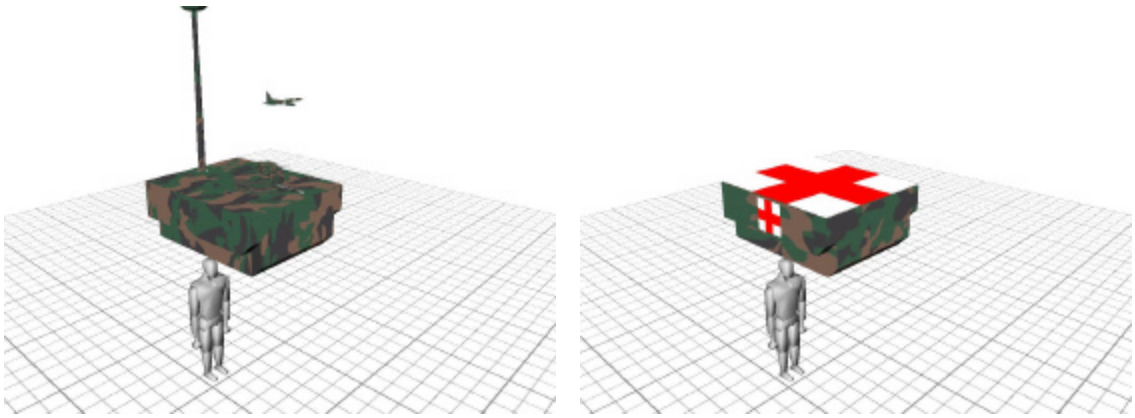
(Conceptual Sketch Assault Gun Module)



(Conceptual Sketch Air Defense Module)



(Conceptual Sketch Mortar-EFSS Module)



(Conceptual Sketch Reconnaissance Module) (Conceptual Sketch Ambulance Module)

Figure 1-1[6]

As a system of systems, the variants will be multi-mission-capable across the spectrum of conflict. The variants are also to be expeditionary. That is, they must be deployable, employable, survivable, and sustainable. Forces equipped with these capabilities will extend the operational reach of the geographic Commander-in-Chiefs and provide the Joint Force Commander with a range of flexible options in one package. This offensive combat vehicle capability should extend from the littorals and have operational-level effects.[7]

[6] NWSC Caderock and Booz-Allen. Unpatented Conceptual Sketch Software for MEFFV Program Office, 2001.

[7] Col Dennis W. Beal, USMC, PM-MEFFV, "MAGTF Expeditionary Family of Fighting Vehicles (MEFFV)" Unpublished Presentation to Marine Corps University Command and Staff College, 21 September 2001, 4.

Chapter 2

CONCEPTUAL FRAMEWORK

HUMAN ELEMENT AND OPERATIONAL MANEUVER

In order to understand the requirements for and potential impact of MEFFV, it is important to appreciate the combat environment in which it would operate. This section will address this aspect and, in particular, the role of MEFFV in maneuver warfare. As the human element and the decision cycle are fundamental to maneuver warfare, they must be considered when defining the necessary capabilities in order for MEFFV to achieve operational-level objectives. The intent here is to equip Marines, not to have humans man equipment. Central to the human element in war is the decision cycle that creates tempo, a concept first developed by Colonel John Boyd. The Boyd Cycle of observe, orient, decide, and act, termed the "OODA Loop," if implemented to the benefit of a joint or multinational force, is the basis of maneuver warfare theory and is thoroughly integrated in basic Marine Corps doctrine beginning with MCDP 1:

> "Maneuver warfare is a warfighting philosophy that seeks to shatter the enemy's cohesion through a variety of rapid, focused, and unexpected actions which create a turbulent and rapidly deteriorating situation with which the enemy cannot cope."[8]

The essence of maneuver is to create and exploit ambiguity, deception, fast maneuvers, and efficiency and to create an enemy that is disoriented, disrupted, and overloaded. For the enemy, maneuver conflict generates friction, loss of cohesion, paralysis, and collapse.[9]

---

[8] MCDP 1 *Warfighting* (Washington, DC: Headquarters, United States Marine Corps, 1997), 73.

[9] John R. Boyd, Col, USAF, "Patterns of Conflict," Unpublished Briefing, December 1986, slide titled "Essence of Maneuver Conflict."

Boyd's OODA Loop theory, in turn, focuses Marine Corps doctrine on Carl von Clausewitz's enduring themes of the human element in conflict, mental and moral aspects, and dueling wills.

The OODA Loop approach within maneuver warfare clarifies the terms of tempo, the means of reconnaissance, and the endstate of initiative in offensive action by training decision makers to understand its components.[10] And, this approach makes it necessary to take into consideration the depth of the battlefield, deep operations, and operational maneuver. To do so, one must view the battlefield longitudinally versus laterally with regard to force maneuver. Operations throughout the entire depth of the battlefield should attack vulnerable areas containing operationally-significant enemy lines of communication, industrial resources, or population centers, obliging enemy forces to react to threats outside the isolated tactical zone. (See Figure 2-1)

[10] Daniel Moore and Christopher Yunker, "Carriers Pack and Airborne Cavalry," in *Spirit, Blood, and Treasure: The American Cost of Battle in the 21st Century*, ed. Donald Vandergriff (Novato, CA: Presidio, 2001), 219.

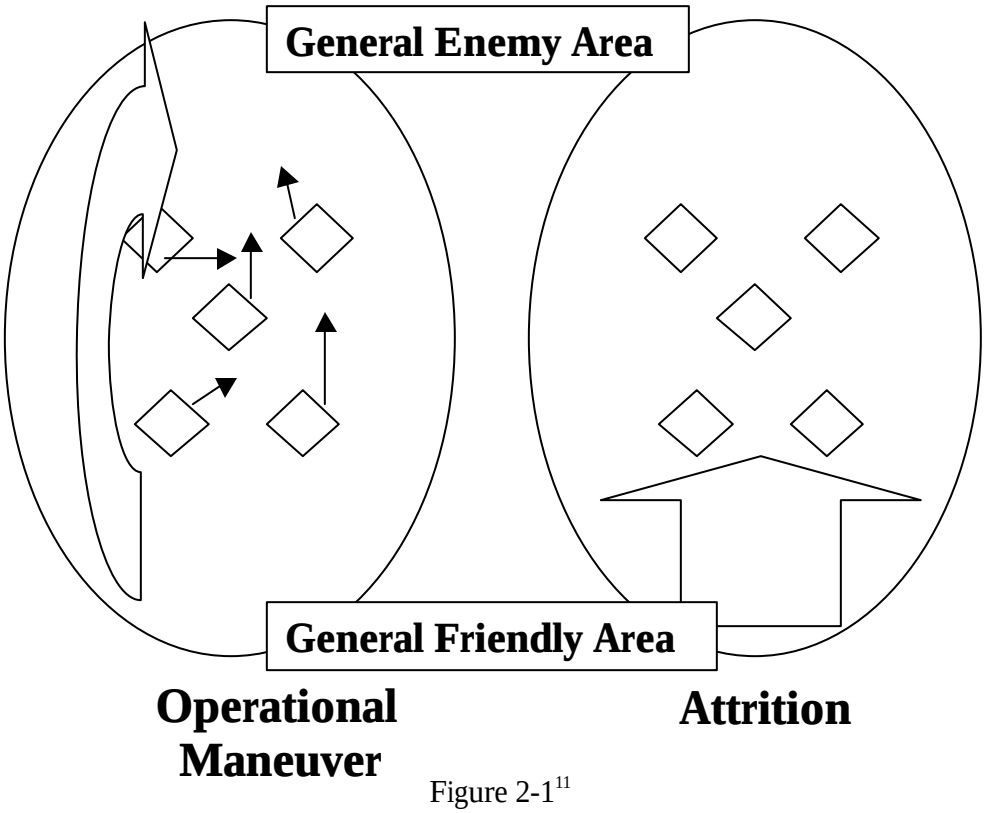


Figure 2-1[11]

DEEP OPERATIONS VS OPERATIONAL MANEUVER

The MEFFV program above all must provide capabilities oriented on the conduct of operational maneuver, which is becoming the Marine Corps' central operational concept. Indeed, the innovative Deep Strike series of experiments, which the USMC conducted, validated the need for a unit that must be capable of operational maneuver. Deep operations differ from operational maneuver. Although deep operations can produce operational effects, they can not be classified under the definition of operational maneuver. Instead, deep operations are often single synchronized events that shape the tactical battlefield forward of the close battle:

> "Deep operations are those directed against enemy forces and functions beyond the close battle. They are executed at all levels with fires, maneuver, and

[11] Christopher Yunker, "Over the Horizon," in *Spirit, Blood, and Treasure: The American Cost of Battle in the 21st Century*, ed. Donald Vandergriff (Novato, CA: Presidio, 2001) 3.

> leadership. Deep operations affect the enemy through either attack or threat of attack. They expand the battlefield in space and time to the full extent of friendly capabilities."[12]

This is to be contrasted with operational maneuver:

> "[Operational Maneuver] includes moving of deploying forces for operational advantage within a joint operations area and conducting maneuver to operational depths (for offensive and defensive purposes). … Operational formations are actually composed of tactical forces moving to achieve operational or strategic objectives."[13]

Deep operations have rarely achieved the synergy required in campaigns to achieve operational success. Deep operations shape the battlefield for decisive action in the close zone by using deception, fires and maneuver, psychological operations, and information operations. In contrast, operational maneuver - - while conducted in the deep zone - - employs mobile, lethal, and survivable forces capable of creating superior tempo beyond the orientation of an enemy's tactical capabilities to collapse its means to fight. As such, operational maneuver attacks operationally significant objectives and creates enemy vulnerabilities.

Operation maneuver requires forces on the ground to rapidly attain operational success. The civilian and military leadership have maintained a false reliance on the ability of air power and precision guided munitions to strike operational and strategic objectives, since air power alone, as a single arm of combat forces, does not create a synergistic effect at the operational or strategic level. Air power is capable of striking strategically important targets; however, it does

---

[12] *Field Manual (FM) 100-5, Operations*, (Washington, DC: Headquarters, Department of the Army, 1993) 6-14.

[13] Chairman of the Joint Chiefs of Staff Manual (CJCSM) 3500.04B, *Universal Joint Task List, Version 4.0*, (Washington, DC: GPO, 1 October 1999), 2-299.

not combine effects in a campaign that could rapidly produce victory at the operational or strategic level of war.

To be sure, the U.S. Air Force and some special operations units have conducted deep operations. However, small units on the ground deep within enemy-controlled territory without mobility and the organic combat power sufficient to destroy enemy reserves are ineffective for operational maneuver. Although the Air Force conducts deep operations with air interdiction to raise the enemy's cost of war to an unacceptable level and to temporarily cut off supplies and reserves from the close battle, the predicted effects and actual results of Air Interdiction deep operations have not been close to being equal. Air interdiction theory is flawed in that it fails to recognize the enemy's decision cycle and the nature of change and adaptation inherent in the human element of war. Physical destruction in limited objective war, short of annihilation theories best suited for nuclear weapons, creates siege conditions that take effect over long periods of time. The use of the air arm alone in deep operations fails to achieve operational maneuver. It focuses on the physical element of destruction and fails to direct efforts against the full dimensions of conflict, to include the human element and the decision cycle.[14]

For example, during Operation Allied Force (Kosovo) in 1999, the synergy required to achieve campaign success did not exist, as the single-arm approach dominated planning and execution.[15] Over time, destruction of targets by air power may deteriorate a limited will. However, air power alone does not simultaneously reduce tactical military means, operational

---

[14] Franklin C. Spinney, "Interference - Interception - Isolation: An Inquiry into the Moral, Mental, and Material Effects of Deep Operations," Unpublished Working Paper, March 1985, 1-5; and Christopher Yunker, "Over the Horizon," in *Spirit, Blood, and Treasure: The American Cost of Battle in the 21st Century*, ed. Donald Vandergriff (Novato, CA: Presidio, 2001), 232?

[15] Moore and Yunker, "Carriers Pack and Airborne Cavalry," 222-223.

targets, and the strategic focus for conflict - - the center of gravity. As a hub of power, the center of gravity must be attacked at the operational level simultaneously with multiple arms - - ground and air - - to rapidly reduce its positive effects on enemy command and control, cohesion, freedom of maneuver, and endurance.

As an alternative approach, in 1996, Lieutenant General Anthony Zinni as Commander I MEF formed an Operational Maneuver Group (OMG) to study the capabilities of a Marine Corps ground option to conduct deep maneuver supported and sustained by air power. The result that was anticipated and attained was precisely an operational maneuver capability, even though this was achieved by traditional tactical means with equipment that is already fielded, such as LAVs or those systems about to be fielded in the near future, in particular the AAAV and the V-22. The OMG, chaired by the commanders of the 1st and 3rd Light Armored Reconnaissance (LAR) Battalions, developed a series of milestone exercises to validate the required capabilities of strategic lift, air delivered sustainment, long-haul communications, joint deep air support, joint close air support, and extended overland movements. The milestones culminated in Exercise Deep Strike that was conducted in the Southwest United States in August 1997. Formed within a Special Purpose MAGTF, three LAR Battalions operated in a 60,000-square mile-Area of Operations (AO). The longest single overland movement by a LAV unit was 700 miles. The significance of the size of the AO and the distances moved was to demonstrate the effect of a lethal and mobile force behind the orientation of an enemy's tactical capabilities. Units deployed to the AO by landing from amphibious shipping and strategic airlift. Forces exercised combined arms live fire that included joint close air support and B-1B-delivered munitions for deep air support. The force sustained itself by air-delivered supplies of

classes I, III, V, VII, and IX and recovered "battle damaged" vehicles by C-130 aircraft. Units exercised command and control by communicating successfully across the depth of the AO. The exercise fought threats and executed tasks across the spectrum of conflict. As such, exercise Deep Strike validated the ability of current tactical units to conduct operational maneuver.[16] However, the exercise surged assets beyond their normal operating capability and was successful even with some deficiencies.

Combining the effects of air power across the depth of the battlefield with a combined arms force, also capable of maneuvering against operational and strategic targets, affects the mental dimension of operational maneuver. The mental and moral dilemma created by the physical threat of a combined arms ground maneuver force in the rear of geometrically positioned forces is particularly significant. If the ground maneuver force is capable of making faster decisions and generating unmatchable tempo, its presence alone creates a dilemma for the enemy. If the enemy commits forces to give chase, he then dilutes his own planned efforts, creates gaps for exploitation, and has to react to a force with superior and unmatchable tempo. If the enemy ignores the operational maneuver force, he suffers from the effects of its combat power against operational and strategic targets that destroy his center of gravity, leaving tactical forces isolated. Combining the effects of an operational maneuver force with air power across the operational depth of a battlefield creates the synergy required for future campaigns to be fought at the operational and strategic levels.

---

[16] LtCol Thomas B. Sward and LtCol Tommy L,. Tyrell, Jr., USMC, "Marine Light Armor and Deep Maneuver." *Marine Corps Gazette* December 1997, 16-20; I participated in the planning, execution, and evaluation of the OMG milestones and Exercise Deep Strike.

FUTURE WARFARE

To analyze the threats in future conflicts, an understanding of current threat proliferation is necessary to validate the capabilities required for MEFFV. As U.S. global power flourishes, competitors will rise with opposing objectives. International consensus on defeating these competing threats will be made more complicated by regional, cultural, economic, and interest-based decisions. Unilateral action by the U.S. may well be necessary in situations that threaten or directly attack the survival and vital interests of its National Security Strategy. The majority of circumstances that will involve joint forces, however, will require regional, possibly global and multinational consensus and participation by other countries.

Future conflicts will involve a variety of destructive capabilities that will be proliferated through the information age. T-72 tanks, BTR-60 and BMP-3 armored personnel carriers, and advanced fighter aircraft are common to many small armies today, and even more advanced fighting platforms will be sold on open markets to any bidder in the future. These new assets could include missiles, nuclear warheads, and chemical and biological munitions.

The threat environment in which the MEFFV will have to operate on the future battlefield will include elements across the full spectrum of war. The spectrum will range from operations-other-than-war (which include peace operations of presence, humanitarian assistance, peace keeping, and peace enforcement), to limited objectives such as raids and non-combatant evacuation operations, to mid- and high-intensity conflicts. The threats across the spectrum will include aggressive civilian populations, non-state actors, non-rational terrorists, paramilitary groups, and organized armies. It is likely that future operations will engage in the full spectrum of conflict involving multiple threats simultaneously. For example, a MEFFV-equipped unit

tasked with peace keeping and security for a humanitarian mission would be dealing with cooperative and uncooperative factions of a civilian populace within an urban environment. Such a unit must be equipped to protect the force from asymmetric terrorist attacks using conventional means, chemical, or biological agent weapons. Actively or passively defending against this non-rational threat, the MEFFV-equipped unit must also be prepared to fight an organized conventional army. Fighting these threats simultaneously in a "three block war" situation, defines the requirement for the Marine Corps' 1st echelon to be multi-mission capable.

Chapter 3

DOCTRINE

JOINT VISION 2020

The Chairman of the Joint Chiefs of Staff's *Joint Vision 2020* orients doctrinal and operational innovation to fulfill the anticipated needs of future campaigns. The MEFFV program is one such operational innovation which can play a key role in enabling the Marine Corps to contribute to this future vision. Joint forces in the future - -unrestricted by the date of 2020 - - will need to have "Full Spectrum Dominance." This will be achieved by gaining and maintaining supremacy of all battlespace functions against any threat across the spectrum of conflict. To achieve this, the joint force of the future must be "persuasive in peace, decisive in war, and preeminent in any form of conflict."[17] U.S. Forces must be capable of power projection, overseas presence, and strategic agility to define the operational concept of the future joint force. Depending on the fulfillment of an information revolution, the future force will secure capabilities of "dominant maneuver, precision engagement, focused logistics, and full dimensional protection."[18] This will depend on the innovation of doctrine, the adaptation of organizations, and progressive training and education. Innovative leaders and emergent technology are also factors.[19]

---

[17] *Joint Vision 2020*, 1.

[18] *Joint Vision 2020, 2.*

[19] *Joint Vision 2020*, 3.

The strategic context of the *U.S. National Security Strategy* must assume continued global U.S. interests involving engagement across the entire spectrum of war with a wide variety of regional threats. Future military operations will involve a joint force operating within a scope of greater U.S. interagency coordination, multinational coalitions, and international organizations. The MEFFV must enhance a unit's ability to operate in this complex cooperative environment.

EXPEDITIONARY MANEUVER WARFARE

Expeditionary Maneuver Warfare (EMW) is the Marine Corps' capstone concept for the 21st century that will guide the Corps to its realization of *Marine Corps Strategy 21*, the Marine Corps' vision for the future. It emerged as an effort to provide future Joint Force Commanders with a powerful and flexible force to assist and assure allies and deter or defeat all adversaries across the spectrum of conflict. The concept rests on the integrating concepts of how the Marine Corps will organize, deploy, and employ, and encompasses the operational concepts of OMFTS, Sustained Operations Ashore (SOA), and Other Expeditionary Operations (OEO). EMW focuses on joint and multinational enabling, strategic agility, operational reach, tactical flexibility, and support and sustainment. The capstone concept is based on the expeditionary nature of the Marine Corps, its maneuver warfare philosophy, and on the MAGTF.

UNIVERSAL JOINT TASK LIST

The Universal Joint Task List (UJTL), (a CJCS manual that standardizes the requirements for the planning, conduct, and evaluation of joint and multinational training), identifies operational maneuver as a required task for joint and multinational forces. These forces must be capable of

maneuver to extend forces to operational depths in order to achieve a relative advantage over the enemy and directly accomplish operational or strategic objectives. To maneuver at the operational level of war, a force must be capable of concentrating at a decisive point prior to enemy detection, using speed, all-terrain mobility, and great range.[20] The UJTL addresses the requirement for operational maneuver capable ground forces, while the Army and Navy Universal Task Lists do not. The service task lists at present do not mirror the joint requirement, and therefore do not organize forces for operational maneuver. However, the Marine Corps is working toward meeting the joint requirement through doctrinal innovation, training, organizational adaptation, and sound technology investments. MEFFV technology capabilities will compliment the non-material innovations. Together, they will provide future Joint Force Commanders with a solution for the joint requirement - - operational maneuver.

[20] CJCSM 3500.04B, *Universal Joint Task List*, 2-302.

Chapter 4

TECHNOLOGY APPROACH

The MEFFV response to the technology requirement is a "Leap Ahead" approach, which will determine the future needs and direct procurement of technologies available in 2015. The needs determine the focus for technology development by setting technology investment priorities. The Program Manager's Office identified five requirements: 1) reduced gross weight/increased survivability, 2) autonomous defensive systems, 3) fuel conservation or elimination, 4) regenerative weapons, and 5) multi-spectrum tactical awareness. The correlating technology focuses are: 1) advanced lightweight composites that increase survivability, 2) vehicle integrated defense and survivability suite, 3) non-petroleum based propulsion, 4) directed energy weapons, and 5) sensor data fusion. These focuses for technology will be referred to as the five technology spikes or thrusts.[21] The technology thrusts are interdependent, which causes problems for program management of individual technology contracts.

LIGHTWEIGHT COMPOSITE MATERIALS

The technology thrust of advanced lightweight composites is intended to reduce combat weight and to increase survivability. The reduction in weight is relatively measurable in that the M1A1 weighs sixty-eight tons, while the assault variant MEFFV will weigh only thirty tons. Similarly, the reconnaissance variant will weigh less than the current LAV variants, which weigh an average of fourteen tons. By reducing weight, MEFFV platforms will be more maneuverable

[21] Beal, 6.

and have a smaller signature that will reduce chances of threat detection. Additionally, lighter MEFFV platforms will be more easily deployed in limited amphibious assault lift. The challenge to the technology thrust is to reduce combat vehicle weight while simultaneously increasing the survivability of the systems and the crew. Achieving this combination requires experimentation with composite materials, titanium alloys, and synthesized metals. The goal of the ballistic integrity of the new armor must match the capabilities of threat systems to protect against less than 105mm calibers. The signature, or height, of the vehicle must be less than 2.5 meters to offset the lethality of super high velocity titanium rod projectiles, although no armor system can be expected to sense and defeat this threat completely. The hull must have frequency selective compounds to reduce the need for vulnerable external antennas. Sensors must be imbedded and not exposed. Additionally, the composites used must reduce the thermal signature or possibly control its thermal image, making the MEFFV stealthy to generation III Forward Looking Infra Red (FLIR) threat systems.[22]

VEHICLE INTEGRATED DEFENSE SYSTEM

The Vehicle Integrated Defense and Survivability (VIDS) Suite as a technology spike will add to the combat vehicle's survivability. Research and experimentation will focus on the areas of active armor protection, sensor suites, real-time multi-spectral signature management, and real-time adaptive response systems.[23] As joint and adversary forces employ Directed Energy weapons such as electromagnetic pulse and high-energy lasers on the battlefield, MEFFV must

[22] Beal, 8.

[23] Beal, 9.

be hardened to operate in this environment. These areas and emergent capabilities will improve the survivability of the component systems.

NON-FOSSIL FUELS

OMFTS and STOM require MEFFV-equipped forces to have the range necessary to envelop the enemy's tactical area of influence. This range can easily exceed 400 miles, and MEFFV must be capable of ranging the area of operations for operational maneuver, loiter, and withdrawal. Fossil fuels are heavy, their containment tanks take space, and they do not provide adequate range, without refueling, to conduct operational maneuver. Non-fossil fuel technology will require high efficiency engines and look into the use of inertial confinement fusion. Other sources of energy are available now in realistic technology readiness levels that make them valid options for the timeframe of fielding. This thrust must increase the range and power of the MEFFV while simultaneously reducing the logistical requirements that have been traditionally tied to combat vehicle units.[24]

DIRECTED ENERGY WEAPONS

Operational maneuver is less complex and lower risk with increased lethality that does not require significant logistical resupply. Directed Energy (DE) weapons that regenerate will increase lethality and reduce logistical requirements. Research in the area of this technology thrust will explore the use of particle beams and lasers to produce a primary weapon for

[24] Beal, 7.

MEFFV. High Energy Lasers (HELs) categorized as Electro-Optic devices produce a directional, narrowly focused beam that at high powers can cause thermal damage and destruction of targets at stand-off distances. Solid state lasers would take energy from the vehicle power plant, creating an unlimited number of shots. Targets should be classified as human and military hardware. The HELs should be able to regulate the laser power to produce non-lethal and lethal effects on both target classifications. High-power radio frequency (RF) DE weapons should be explored to attack other targets such as electronic equipment. In this role, RF DE weapons could be used for Suppression of Enemy Air Defense (SEAD), as Electronic Attack for destruction of enemy communication, and for platform defense against air-to-surface and surface-to-surface missiles. However, since laser technology and particle beams are subject to environmental conditions such as dust clouds and rain that reduce their effectiveness, secondary conventional weapon systems must be included.[25]

SENSOR FUSION DATA

The technology thrust of sensor data fusion will pursue systems that integrate the operating functions of the MEFFV. It will serve as an interface that will include a Vehicle Smart Center, VIDS Microprocessor Interface, V-tronics Suite, Imbedded Diagnostics/Prognostics, Multi-spectral Integrated Sensor, and a Core Architecture of a databus with unlimited expansion capability.[26] Sensor data fusion will integrate system hardware and software of MEFFV and tie into the theater C4ISR network. This new databus will increase bandwidth and allow system

[25] Beal, 7.

[26] Beal, 8.

expansion by accepting plug-in subsystems. Sensor data fusion makes MEFFV adaptable. With this integration suite, MEFFV will be linked to all joint networks making it interoperable.

Chapter 5

CAPBILITIES REQUIRED

The MEFFV Reconnaissance Variant must be deployable, expeditionary, employable, and sustainable. To take the methodology of this thesis from concepts and doctrine to concrete capabilities required of a force to conduct operational maneuver, capability sets based on battlefield operating systems or functions will be used: Maneuver, Fires, Intelligence, Logistics, Command and Control, and Force Protection. The battlefield operating systems or warfighting functions are chosen simply to organize the capabilities-based requirements.

To form a family of vehicles capable of creating complementary combined arms effects and sustained independent operations, general module requirements must be identified. To meet the challenges of a variety of future conflict possibilities, a family of module variants must include: an assault gun, an armored personnel carrier, an indirect fires platform, an air defense variant, an engineer variant, a command and control platform, a logistics hull, an ambulance variant, and a maintenance variant. The requirements of these baseline variant modules will be further explored in the analysis of the battlefield operating systems.

MANEUVER

> "Dominant Maneuver is the ability of joint forces to gain positional advantage with decisive speed and overwhelming operational tempo in the achievement of assigned military tasks. Widely dispersed joint air, land, sea, amphibious, special operations, and space forces, capable of scaling and massing force or forces and the effects of fires as required for either combat or non-combat operations, will secure advantage across the range of military operations through the application

> of information, deception, engagement, mobility, and counter-mobility capabilities."[27]

Joint and Marine Corps doctrine recognize the inherent operational mobility of naval forces to extend operational reach.

> "Maneuver, integrated with fires, will be linked to and influenced by the JFC's battlespace shaping operations and directed toward achieving operational effects. Innovative technologies will provide Marines enhanced mobility to cross greater distances and reduce the limitations imposed by terrain, weather, and access denial systems."[28]

To maneuver across the operational depth of the future battlefield, the Joint Force Commander must be able to easily deploy the first-choice asset. The size and weight of the MEFFV Reconnaissance Variant is important as it relates to deployability, since large, heavy equipment requires more lift assets to deploy a force of significant size to conduct operational maneuver. At approximately ten tons, multiple vehicles would meet the Aircraft Cargo Limit (ACL) of U.S. strategic airframes. As a CONUS or forward-based unit on contingency alert, the MEFFV would be transportable by C-130, C-17, and C-5 assets. Cubic size is the primary factor in determining the number of MEFFV Reconnaissance Variants that would be transportable in each of the strategic airframes. However, air will not be the primary method for transporting or deploying MEFFV units, and naval expeditionary constraints will be used to approximate the size of the asset.

Doctrine and concepts for the Marine Corps as a 1st echelon joint or multinational enabler require forces and their assets to be expeditionary naval forces that extend operational reach. As

---

[27] *Joint Vision 2020*, 20.

[28] Commandant of the Marine Corps, *Expeditionary Maneuver Warfare* (Washington, DC: Headquarters, United States Marine Corps, 2002), 14.

an expeditionary platform, the MEFFV must meet additional size constraints. The MEFFV will not have an Over-the-Horizon (OTH) amphibious capability. Instead, it must be deployable from OTH to shore on existing and enhanced landing craft, primarily the LCAC. The LCAC's deck is twenty-seven feet wide and sixty-seven feet long and capable of carrying seventy tons of cargo on the 1809 square-foot cargo deck. Therefore, the LCAC could carry the combined weight of six ten-ton MEFFVs, which serves as a constraint. The Reconnaissance Variant should be twenty feet long and nine feet wide in order to fit six on the limited deck and still allow space for maintenance of the vehicles and of the LCAC itself while underway.

Once the MEFFV force is transported to shore, it must be capable of maneuvering quickly relative to enemy dispositions in order to gain operational advantage. The MEFFV force should be employed by landing where the enemy is not physically present or where he is not capable of detecting the landing and maneuvering reserves. In the case of an opposed landing, the amphibious force is most vulnerable on the beach. Extending the range, speed, and mobility of the MEFFV will increase the operational reach of the expeditionary naval forces, allowing flexibility to choose more distant shores that are out of the enemy's area of influence. With a range of 800 miles, the MEFFV-equipped units could land outside of an enemy's battlespace, undetectable to enemy collection systems, and move quickly overland to operational target areas.

Mobility relative to future enemy capabilities will define the capabilities required by MEFFV and the mobility required to accomplish this operational surprise demands improved speed. On improved surface roads, a hull capable of a cruising speed of seventy mph would deny other existing systems forecasted to be abundant in the near future from catching or maneuvering against a MEFFV. Similarly, the cross-country speed of forty mph would produce the same

advantage. The current LAV is capable of climbing a grade of only 60% and traversing a slope of 30%. Many accidents have occurred due to LAVs' sliding down steep grades and rolling over on slopes. Increasing the grade capability to 65% and the slope capability to 40% would improve the MEFFV mobility over various terrains. To improve range, speed, grade and slope capabilities, the MEFFV must be a multi-axle wheeled hull. At a length of twenty feet and weight of ten tons, a three-axle, six-wheel chassis would suffice. The suspension should be independent and pneumatically regulated to improve mobility, and a clearance of two feet would be sufficient in traversing ditches and other obstacles. Water obstacles such as rivers, streams, and lakes must be traversable if they can not be bypassed or if they are to be used as unsuspected avenues of approach. Therefore, similar to the LAV, the MEFFV must have a limited swim capability. Integral to the swim capability of the MEFFV is hull integrity. Sealing and engineering the hull, plus balancing module varieties for ballast therefore will be important considerations in the design phase.

An all-weather, nearly all-terrain, mobile MEFFV-based combined arms force would significantly improve the options for a Joint Force Commander to exercise operational maneuver with an expeditionary 1st echelon unit. Improving mobility factors beyond the existing capabilities that will be proliferated in future threat forces will facilitate a MEFFV force to maneuver beyond the depth of an enemy's tactical capabilities.

FIRES

Maneuver warfare uses fires, both direct and indirect, to create a dilemma for the enemy for a friendly force to exploit, and superior organic fires of a force conducting operational maneuver

are critical.[29] Fires must be capable of lethal and non-lethal effects for a maneuver's exploitation. The MEFFV fires system must have superior target detection, tracking, and engagement options - - organic as well as linked to the joint force and theater assets.

The fire support systems or inorganic assets to be used by the MEFFV units and its organic fires must be responsive and "smart" in order to prevent fratricide. Therefore, the fires systems of the MEFFV must communicate through the C4ISR network. Likely indirect fire missions required by the MEFFV-equipped force will be suppression, obscuration, area denial, and harassment. Likely direct fire missions are suppression, harassment, and destruction. Weapons systems must back-up each other, thus providing redundancy. To the maximum extent possible, ordnance should be regenerative - - energy bursts versus conventional ammunitions - - and not require heavy logistical resupply that is necessary today after a conventional ammunition load is expended.

The direct fire systems of the MEFFV must be capable of creating the desired effects of each modular variant. As the mainstay of the reconnaissance variant family of vehicles, the Assault Gun module must be equipped with multiple direct fires systems. The technology approach to source Directed Energy (DE) weapons must produce a regenerative main gun capable of non-lethal and lethal fires effective against targets from humans to hardened equipment, including tanks. As the spectrum of conflict in the future compresses, a force conducting operational maneuver will need to minimize collateral damage in a built-up area, deter or disperse hostile

[29] *Joint Vision 2020*, 2; "Precision Engagement is the ability of joint forces to locate, surveil, discern, and track objectives or targets; select, organize, and use the correct systems; generate desired effects; assess results; and reengage with decisive speed and overwhelming operational tempo as required, throughout the full range of military operations."

crowds, and destroy enemy armor vehicles, all within a given mission. This main gun must have a rapid recycle rate that allows six or more bursts per minute. The weapon would fire line of sight with a range limited only by the fire system's ability to detect, identify, and track threat targets. This range should be a minimum of six kilometers in order to provide superior stand-off range relative to forecasted threat systems like the T-72 and BMP-3 that have ranges of four kilometers. The DE main gun must be backed up by an alternate conventional gun capable of lethal fires in environments that prevent the use of DE weapons, such as dense fog and dust. A 30mm gun with high explosive (HE) and armor piercing telescoping munitions must range a minimum of six kilometers, again to provide superior stand-off range relative to forecasted threats. All modules should be capable of close-in defense in terrain - - urban and thick vegetation - - that conceals dismounted threats. While sensor systems should detect threats at stand-off ranges, the threat of hostile humans in urban environments will not likely be detected by such systems. Even if the MEFFV cannot detect a human threat, it would still need a weapon to suppress it. A lethal suppression tertiary gun such as the 7.62mm GAU would provide the close-in fire superiority necessary to deter, suppress, and destroy close-in human and light skinned vehicle threats. This close-in tertiary weapon is important, as urban environments are a likely area of employment for MEFFV.

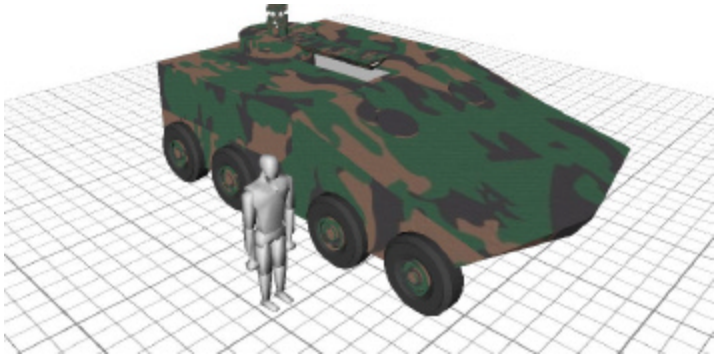


Figure 5-1; Conceptual Sketch of Assault Gun Variant[30]

Having a force with organic indirect fires facilitates the preferred combined arms engagement. The family of reconnaissance variants must have an organic indirect fire module capable of accurately ranging eight to thirteen kilometers, since the range of the indirect fires platform must coincide with the possible frontage of the unit it supports. Currently, the 120mm Expeditionary Fire Support System (EFSS) is capable of delivering highly lethal fires at this range. The firing system must receive data burst fire request transmissions and automatically compute, balance, and lay the mortar to allow the timely combined arms effect desired. The munitions must support the variety of mission requirements, and include HE, White Phosphorous (WP), Illumination (visible and infrared), Dual Purpose Improved Conventional Munitions (DPICM), Rocket Assisted Projectiles (RAP), and Precision Guided Mortar Munitions (PGMM). The EFSS module must also have a counter-fires radar capability tied directly to the ballistic computer to provide a counter-battery capability. The EFSS should have a maximum rate of fire of 10-16 rounds for one minute and a 4-round per minute sustained rate. These rates of fire create the effect of suppression desired that allows the force to maneuver on

[30] NWSC Caderock and Booz-Allen. Unpatented Conceptual Sketch Software for MEFFV Program Office, 2001.

the threat. The EFSS module must have the ability to become fire-capable and to displace in a short time. That is, the EFSS should be fire capable as soon as the vehicle stops and should be able to displace without locking the system prior to the vehicle moving.

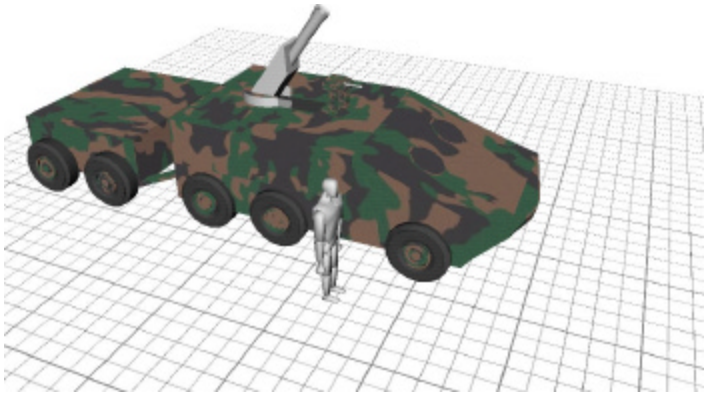


Figure 5-2; Conceptual Sketch of EFSS Variant[31]

The MEFFV Air Defense module must provide low to medium altitude defense against threat aircraft and missiles, such as the MiG-29, MI-24, and tactical and theater ballistic missiles. The low altitude defense capability should be met with a missile and gun system similar to the current LAV-AD platform that includes Stinger missiles and a GAU-12 25mm automatic gun. The medium altitude defense capability could be achieved by a DE weapon with greater range than conventional munitions. The command and control of the Air Defense module must be tied to theater radars that will be organic to the Marine Air Command and Control System in order to integrate the Joint Operations Area Air Defense systems. The Air Defense module must be capable of receiving target cues and assignment information through digital communications terminals over UHF, HF, and satellite communications frequencies.

[31] NWSC Caderock and Booz-Allen. Unpatented Conceptual Sketch Software for MEFFV Program Office, 2001.

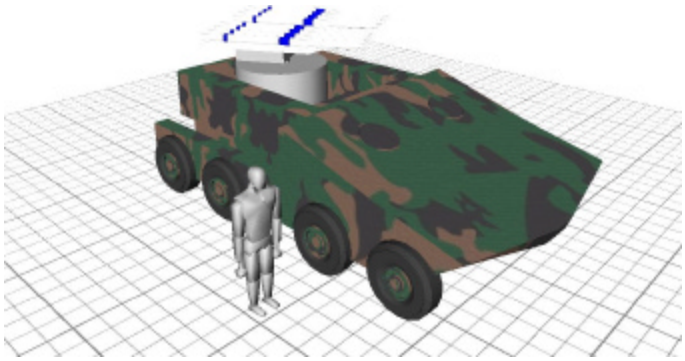


Figure 5-3; Conceptual Sketch of Air Defense Variant[32]

INTELLIGENCE

Intelligence is a function of command that enables the warfighter to make sound decisions based on analyzed information quicker than a foe and protects friendly information, supporting force protection.[33] Intelligence provides knowledge as a basis for decision and action. In support of maneuver warfare, the function of intelligence must create advantage for the exploitation of maneuver and fires. For the MEFFV program, linking the Marine making decisions during operational maneuver to theater intelligence systems such as the Joint Deployable Intelligence Support System (JDISS) is a critical link not available to current vehicle platforms.

Within the context of the information revolution, intelligence, when used as a system for collecting, analyzing, and disseminating information, naturally will be more complex. The MEFFV program must acknowledge this reality and acquire joint systems that integrate MEFFV

---

[32] NWSC Caderock and Booz-Allen. Unpatented Conceptual Sketch Software for MEFFV Program Office, 2001.

[33] MCDP 2 *Intelligence* (Washington, DC: Headquarters, United States Marine Corps, 1997), 5-6; "Intelligence strives to accomplish two objectives. First, it provides accurate, timely, and relevant knowledge about the enemy (or potential enemy) and the surrounding environment. [Second,] it assists in protecting friendly forces through counterintelligence."

equipped units into the joint intelligence infrastructure. More means of collection from the information environment will be available to all advanced nations and non-state actors. The ability to analyze the information and concisely filter it to joint warfighting users more quickly than the enemy can will help generate superior tempo. Also crucial to the tempo race is the ability to protect friendly information. Gaining valid intelligence on the enemy and protecting friendly information - - such as that of MEFFV units conducting operational maneuver - - is important.

Marines equipped with the MEFFV must have intelligence tools that support operations in chaotic, uncertain, and complex situations. The intelligence tools must limit the uncertainty by providing real time information on friendly and enemy units. It must access the Common Tactical Picture (CTP) and Common Operational Picture (COP) through an accessible, rugged, database that is easy to use. It must be a shared network common to all Joint Planning Execution Community agencies. Therefore, the intelligence tools of the MEFFV must meet joint standards for interoperability.

Not only must the Reconnaissance Variant MEFFV be able to access the CTP and COP, but it must also contribute to these databases as an element of the Reconnaissance, Surveillance, Target, and Acquisition (RSTA) cloud. The RSTA cloud is an overlapping array of sensors that communicate information on threat targets. The RSTA cloud links sensors to shooters to minimize the time between target detection and the time to effects on target. The MEFFV sensor data fusion smart center must automatically identify targets to the CTP and COP in order to combine organic capabilities with theater shooter systems.

To move rapidly over operational ranges, the MEFFV must have an organic sensor capability to detect threats beyond line of sight. The tested and effective use of organic Unmanned Aerial Vehicles (UAV) would enhance the abilities of a MEFFV unit to engage threats at stand off ranges or bypass them, passing them off to other theater shooters linked to the RSTA cloud. The MEFFV units must have the ability to launch, control, downlink real-time information and images, designate targets, and recover UAVs in order to improve the intelligence function.

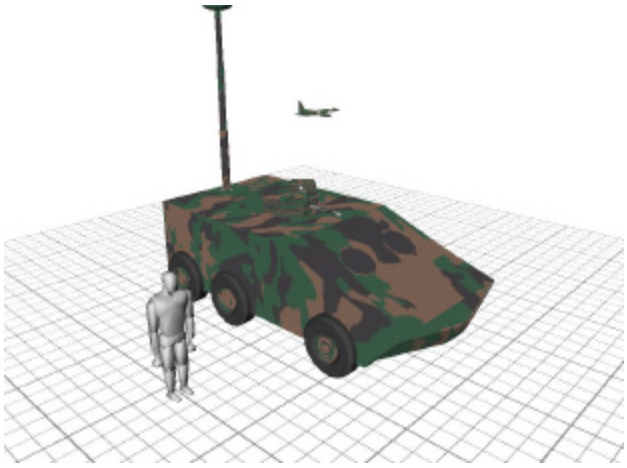


Figure 5-4; Conceptual Sketch of Reconnaissance Variant with UAV[34]

LOGISTICS

The logistics infrastructure of the MEFFV program must be interactive in order to anticipate the needs of the force to sustain tempo at the operational level of war. The logistics focus for MEFFV capabilities must slim down the requirement for maintenance and resupply. In maneuver warfare terminology, logistics must be a center of gravity for the MEFFV for which

[34] NWSC Caderock and Booz-Allen. Unpatented Conceptual Sketch Software for MEFFV Program Office, 2001.

the enemy can find no undermining critical vulnerability.[35] The technology priorities should maintain as a conceptual cornerstone the fact that the MEFFV will be a naval expeditionary element deployed to the most austere environments. Ruggedness of systems is crucial, and the MEFFV units must be virtually self-sustained and independent from sources of resupply.

Logistics is simply "the science of planning and carrying out the movement and maintenance of forces."[36] However, to support OMFTS, amphibious logistics over-the-shore operations (LOTS) provide the doctrine for pushing sustainment from sea to shore without deep-draft port facilities and substantial time. The ability to conduct operational maneuver deep in enemy-controlled areas without secured lines of communication requires new doctrine that uses techniques that have been previously tested, and the Marine Corps has fully adopted the Joint Vision 2020 concept of focused logistics.[37] Therefore, it is necessary to synchronize the concept of focused logistics with the required capabilities for the MEFFV in order for it to execute missions at the operational level on a non-linear battlefield.

Traditional classes of supply must be reduced through technology innovations. For example, power plants for the MEFFV should not require regular refueling intervals. In fact, fossil fuel free technology readiness levels are advancing to be a possible reality in 2020. Parts that traditionally wear, such as braking systems and drive belts, must be improved to reduce the mean time to failure; and replacement parts should require a lower mean time to repair. Lethal

---

[35] MCDP 4 *Logistics* (Washington, DC: Headquarters, United States Marine Corps, 1997), 83.

[36] Joint Chiefs of Staff, *Joint Publication 1-02,* 254.

[37] *Joint Vision 2020*, 24; "Focused Logistics is the ability to provide the joint force the right personnel, equipment, and supplies in the right place, at the right time, and in the right quantity, across the full range of military operations. This will be made possible through a real-time, web-based information system providing total asset visibility as part of a common relevant operational

and non-lethal ordnance in the form of directed energy weapons must regenerate rapidly in order to sustain a high volume of fires, since conventional ordnance required in auxiliary systems must be packaged in less space with greater lethality. On-board systems must monitor, troubleshoot, repair, and automatically report the logistical status of the MEFFV through the C4ISR network to save time and support the precision logistics concept. The MEFFV force must be able to operate without ground lines of communication, and sea-based logistics packages must be air deliverable to safe havens, while at the same time meeting the exact needs of the individual vehicles. Therefore, the family of vehicles built by modular packages must include logistics, ambulance, and maintenance modules to provide the organic general-purpose capabilities required for self-sustained operations.

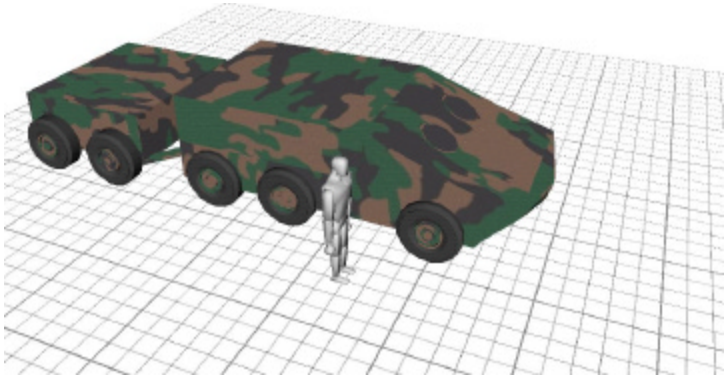


Figure 5-5; Conceptual Sketch of Logistics Variant[38]

picture, effectively linking the operator and logistician across Services and support agencies. Through transformational innovations to organizations and processes, focused logistics will provide the joint warfighter with support for all functions."

[38] NWSC Caderock and Booz-Allen. Unpatented Conceptual Sketch Software for MEFFV Program Office, 2001.

COMMAND AND CONTROL

Decentralized execution to empower subordinates to make decisions and execute based on intent is the function of command and control in maneuver warfare. [39] It is difficult to isolate command and control from the other warfighting or battlespace functions, as it affects each of the other functions, and serves as the glue that bonds the purpose of each function to a common effect. While command and control is a function of the human element, the MEFFV must provide tools that facilitate command and control of the force. As the information age and technologies improve the capabilities of forces - - in terms of range, mobility, lethality, survivability, and information data fusion - - command and control will be more complex, time for decision will compress, tempos will increase, and the ability to operate fluidly in a chaotic environment will be mandatory.[40]

As forces, specifically MEFFV units, move more quickly over longer ranges and as the increasing lethality of fires requires greater dispersion of assets, technologies supporting command and control require further innovations. Long-haul communications assets must support Over-the-Horizon (OTH) operations extending over operational depths. Sensors and improved target detection capabilities, coupled with the effects of longer ranging fires, will increase the requirement for other than line-of-sight bandwidth links. There must be JOA, theater, and global connectivity through a satellite based network. Joint and multinational Identification of Friend or Foe (IFF) systems in order to avoid fratricide in this more fluid

---

[39] Joint Chiefs of Staff, *Joint Publication 1-02,* 80; "The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission."

[40] MCDP 6 *Command and Control* (Washington, DC: Headquarters, United States Marine Corps, 1996), 58.

battlefield, must support the targeting systems. Ultimately, MEFFV must be linked to these C4ISR systems to realize its role in operational maneuver.

In joint and multinational campaigns in which MEFFV will execute missions, interoperability is paramount.[41] As command and control synchronizes the other warfighting functions, interoperability must also be addressed by the technology investment priorities of maneuver, fires, intelligence, logistics, and force protection for MEFFV.

Most closely linked are command and control and intelligence. The intelligence function must increase situational awareness, facilitating faster decisions with appropriately filtered access to the CTP and COP databases. MEFFV command and control will benefit from information superiority through the use of these databases.

Information management through the improved C4ISR network will also support command and control for the MEFFV commanders. However, integral to the human element of command and control, it is important to emphasize the continued need for reliance on mission type orders, intent, and low-level initiative, whatever the technological advances.

FORCE PROTECTION

The first method of protection normally considered today is that which a vehicle's armor provides its crew and on-board systems, and the MEFFV must be survivable against enemy attack. Traditional tradeoffs in weight and, correspondingly, size translate unavoidably to less

[41] Joint Chiefs of Staff, *Joint Publication 1-02,* 221; Interoperability – 1) the ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together; and 2) (DoD only) the condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users. The degree of interoperability should be defined when referring to specific cases.

protection. However, technology readiness levels in composite armor now will make them a reality for procurement by 2020, and the lightweight composites used to form the protective skin of the MEFFV will provide greater protection and require a fraction of the traditional weight tradeoff. The MEFFV protective composites must stop threat direct fire systems less than 105mm, while the vehicle armor must survive near area explosions from threat indirect fire systems up to 155mm. Realistically, technology investments can be expected to achieve full protection for a vehicle against the threat of super high-velocity titanium rods. The penetration capability is too great for a composite material to stop such a round, and sensors will not be able to detect and activate defeating systems in time. Therefore, the MEFFV must have a low signature or be less than 2.5 meters in height to reduce the risk of a hit from such a low-trajectory projectile. However, lightweight composite armor, coupled with sensors linked to reactive defenses and the speed of the MEFFV, should mitigate the risk of engagement, providing active and passive means of protection.

Passive measures must also be included in the protection package to increase survivability. The MEFFV should have a reduced thermal signature in order to make it stealthy on the future battlefields that will be rich with infrared imaging sensors. Reliance on cool-running power plants, shielding friction points, and integrating an environment-sensing system that is capable of matching the vehicle's temperature to its surroundings are passive measures for technology investment priorities.

Apart from the conventional threat, the effects of Nuclear, Biological, and Chemical (NBC) weapons will also be a threat to MEFFV units in future conflicts. Chemical and biological capabilities will proliferate and be used by enemies to deny areas and protect their own

vulnerabilities. Therefore, hull integrity is needed for an overpressure system to allow mobility and crew survivability in NBC-dirty environments in addition to its importance to having a swim capability. The NBC-protection capabilities of the MEFFV should include detection, automatic overpressure defense, and self-decontamination.

The NBC Detection and Defense system should be integrated with a mine counter-measures system, since mine warfare will be a cheap resource for future foes to use in an attempt to reduce the mobility of MEFFV-equipped units. A mine detection system and the capability to neutralize mines prior to activating their destructiveness are crucial, while integrating the mine detection system with the NBC Detection and Defense system will further improve the protection of the crew.

The MEFFV should also be capable of operating in Electronic Attack, Electronic Protect, and Electronic Support environments. These, as well as electromagnetic pulse weapons, will be employed by both friendly and enemy forces, and the MEFFV must be able to operate under these conditions without any system failures.

These multi-layered active and passive protection measures, along with joint C4ISR IFF within the MEFFV capabilities, will reduce the risks of operating independently deep in the operational battlespace. With "Full Dimensional Protection," MEFFV-equipped units as a ready 1st echelon expeditionary means will enable Joint Force Commanders to assign missions capable of operational maneuver.

Chapter 6

CONCLUSION AND RECOMMENDATIONS

Generally, the capabilities analyzed above would equip Marines sufficiently to consistently assign operational objectives to MEFFV units in the future. The Joint Force Commander of 2020 could confidently employ these forces to conduct operational maneuver as the military means to support other elements of national power in order to achieve political goals more efficiently. The picture of improved capabilities to be attained by the MEFFV program is substantial, yet realistic. The technology readiness levels of the capabilities required for a MEFFV unit to conduct operational maneuver must be analyzed and technology experts must meet the viability of the operational needs defined here. The MEFFV program must also include wargame experimentation with Fleet Marine Force units to validate the requirements determined by the analysis in this study. Ultimately, operators and procurement programmers must understand the linkage of technological improvements to non-material changes. This study is one approach to defining capabilities-based requirements. However, the true requirement for operational success by future MAGTFs is one for thinking leaders, doctrinal shifts, organizational adaptation, and training with innovative tactics, techniques, and procedures, and the MEFFV's technological advances must enhance the non-material requirements for operational maneuver by an expeditionary 1st echelon force.

TABULAR SUMMARY OF FINDINGS

The summary of findings from chapter five is consolidated in the following tables, which are categorized by general capabilities required in terms of maneuver, fires, intelligence, logistics, C4ISR, and force protection.

CAPABILITY SET		
Reconnaissance Modules for the Combined Arms Family of Vehicles	Assault Gun	2 crew
	APC	2 crew, 6 dismounts
	EFSS	1 driver, 3 turret
	Air Defense	1 driver, 2 turret
	Engineer	2 crew
	C4ISR	1 driver, 4 crew
	Reconnaissance	1 driver, 2 crew
	Logistics	2 crew
	Ambulance	1 driver, 2 medics
	Maintenance	1 driver, 2 mechanics

MEFFV CAPABILITY SET		
General Hull Capabilities	Power Plant	Non-fossil fuels, eliminate refueling, recyclable lubricants, regenerative parts, extend time to failure, reduce mean time to repair
	Maintenance	Self-diagnostic, troubleshooting, status reporting
	Self-Recovery	20 ton winch
	Suspension/3 axle	Independent, pneumatic, automatic tire pressure regulation,
	Water tight seal	Fording and NBCD overpressure
	Driver compartment	GEN III FLIR, HUD,

MANEUVER CAPABILITY SET		
Size	Weight	10 tons
	Length	20 feet
	Width	9 feet
	Height	7 feet
	Ground Clearance	2 feet
Wheeled Mobility	Range	800 miles
	Road Speed	70 mph
	Cross-country Speed	40 mph
	Slope	65%
	Grade	40%
General Capabilities	Mine Counter Measures	
	Swim capable; not OTH	
	Quiet/Stealth	
	Self Recovery	
	Breaching Equipment	

FIRES CAPABILITY SET		
Assault Gun Module	Primary	DE Weapon
	Alternate	30mm
	Auxiliary	7.62mm GAU
	Load Capacity	300 rds alt/aux each
Organic Indirect EFSS Module	Range	8.2 kms; 13 kms RAP
	Weapon	EFSS 120mm
	Munitions	HE, WP, Illum, DPICM, RAP, PGMM
	ECR/Burst Radius	HE-30m, DPICM-90m
	Lethality	HE - personnel, trucks; DPICM - light armor, artillery; PGM - mobile armor
	Rate of Fire	Max -16 rds/min Sustained - 4 rds/min
	Counter Fires Radar	30 kms
	Load Capacity	40 rds
	C2	AFATDS
Air-Defense Module	DE	Line of Sight
	Alternate	Missiles
	Auxiliary	30mm GAU
	Radar	Slew to cue

	INTELLIGENCE CAPABILITY SET
General	Common Operational Picture
	Common Tactical Picture
	Access Theater/Global Information Assets
	Organic Tactical UAVs
	Interoperable

	LOGISTICS CAPABILITY SET	
General	Modules	Logistics, Ambulance, Maintenance,
	Logistics Packaging	Reduced
	Load/Unload	Crane on/off pallets
	C2 of Logistics	C4ISR data fusion collecting statuses from all MEFFVs

	C4ISR CAPABILITY SET	
General	Secure, multi-channel, digital, OTH comms on the move	VHF, UHF, HF, SatCom, Digital Interface
	Situational Awareness	Filtered CTP/COP
	Prevent Fratricide	Joint IFF
	Versatility	Flexible plug-in pull-out suites
	Interoperability	Joint & Multinational
	Rugged & Protected	Capable in EA, EP, & ES environment

	FORCE PROTECTION CAPABILITY SET	
General	Composite Armor Protection	Direct < 105mm Indirect < 155mm
	NBCD Sensors & Overpressure	Detection, Defense, Self Decontamination
	Reduced Thermal Image	Cool power plant, shielded friction points, auto-adjust thermal image to environment
	Mine Counter Measures	Sensing & neutralizing
	EW protection	EA, EP, ES, EMP

Again, further analysis, experimentation, and wargaming of the findings are prudent. Continued development and refinement of the findings is important to drive technology

investment priorities and research and development contracts. In the next two to three years, technology requirements should be validated against technology readiness levels, which are defined in *DoD 5000.2-R*: *Mandatory Procedures for Major Defense Acquisition Programs and Major Automated Information Systems.* If a capability-based requirement for technology systems is a realistic goal for further technology testing and development, research and development funding should be invested to pursue the realization of the technology innovation.

A thorough evaluation of these hypothesized capabilities-based requirements must be tested by modeling and simulation and Command Post Exercises involving Fleet Marine Force LAV units. The research methodology used to produce the findings in this study was limited in scope to concepts, doctrine, a technology-based approach, and battlefield operating systems or functions. Other methodologies and approaches should also be explored in order to validate, improve, or disprove the findings in the form of capabilities-based requirements.

What will remain constant whatever testing methodology is used is the near future need for a ground force to conduct operational maneuver. A ground combat element capable of maneuvering deep to strike vulnerable targets and loiter in safe havens for other strike opportunities will provide a Joint Force Commander advantageous options. As opposed to the use of strategic bombing and precision guided munitions, a maneuver force has a human decision-making capability to execute missions based on intent. The presence of a ground force threatening operational high-value and payoff targets creates a psychological dilemma for the enemy. The enemy must chase the operational maneuver threat with significant assets or accept the destructive effects of such a force. Operational maneuver is a valid requirement for future

joint forces, and Marines equipped with the MEFFV capabilities examined within this study would make operational maneuver a reality.

BIBLIOGRAPHY

PUBLISHED WORKS

Clausewitz, Carl, von. *On War:* Ed. Michael Howard and Peter Paret. New York: Alfred A. Knopf, Inc., 1993.

Loescher, Michael S., and Chris Schroeder, and Charles W. Thomas. *Proteus: Insights from 2020*. N.P.: Copernicus Institute Press, 2000.

Vandergriff, Donald, Ed. *Spirit, Blood, and Treasure: The American Cost of Battle in the 21st Century*. Ed. Donald Vandergriff. Novato, CA: Presidio, 2001.

PUBLISHED PAPERS

Chairman of the Joint Chiefs of Staff. *Joint Vision 2020*. Washington, DC: GPO, 2000.

Commandant of the Marine Corps. *Expeditionary Maneuver Warfare.* Washington, DC: Headquarters, United States Marine Corps, 2002.

Commandant of the Marine Corps. *Marine Corps Strategy 21*. Washington, DC: Headquarters, United States Marine Corps, 2000.

Commandant of the Marine Corps. *Operational Maneuver From The Sea - A Concept for the Projection of Naval Power Ashore.* Washington, DC: Headquarters, United States Marine Corps, 1996.

Commandant of the Marine Corps. *Ship to Objective Maneuver.* Washington, DC: Headquarters, United States Marine Corps, 1997.

Sward, Thomas B. and Tommy L. Tyrell, Jr., LtCols, USMC. "Marine Light Armor and Deep Maneuver." *Marine Corps Gazette* 81, no. 12 (December 1997): 16-20.

Wilson, Gary I., Col, USCR, Maj Chris Yunker, USMC, and Franklin C. Spinney. "OMFTS: Innovation, Deep Maneuver, and Aviation." *Marine Corps Gazette* 81, no. 12 (December 1997): 21-23.

Yunker, Chris, Maj, USMC. "Mobility Requirements and the 21st Century MAGTF." *Marine Corps Gazette* 81, no. 12 (December 1997): 24-26.

UNPUBLISHED PAPERS

Anderson, Gary W., Col, USMC, and William L. Simpson, Jr., Culebra War Game Series, *Summary Report*. Quantico, VA: Marine Corps Warfighting Lab, May 1999.

Basich, M. T., CDR, USN. *Network Centric Warfare (NCW)*. Information Paper PP&O/SIG, Washington, DC, 3 March 2000.

Beal, Dennis W., Col, USMC, Program Manager-MEFFV. *MAGTF Expeditionary Family of Fighting Vehicles (MEFFV)*. Unpublished Presentation to Marine Corps University Command and Staff College, 21 September 2001.

Boyd, John R., Col, USAF. *Patterns of Conflict*. Unpublished Briefing, Quantico, VA: Marine Corps Research Center Archives, December 1986.

Collins, Patty, Col, USMC, (Ret). *Commander Marine Expeditionary Forces*. Unpublished Presentation, Quantico, VA: Marine Corps Warfighting Lab, 1 April 1997.

Collins, Patty, Col, USMC, (Ret). *Operational Concept For Low Intensity Conflict.* Unpublished Paper, Quantico, VA: Marine Corps Warfighting Lab, 15 February 1997.

Commanding Officer, 1st Light Armored Reconnaissance Battalion. *Operation Order 8-97 (Exercise Deep Strike).* Camp Pendleton, CA: I MEF Sponsored Exercise, 28 July 1997.

Hibbert, Richard E., LtCol, USMC. "Marine Corps Warfighting Concepts for the 21st Century." Unpublished Presentation, Quantico, VA: Warfighting Requirements Divisions, Concept Branch, Marine Corps Combat Development Command, 2001.

Jackson, Timothy J., Maj, USMC. Capable Warrior Exploration (CWE) War Game – 2, Assessment. Quantico, VA: Wargaming Division, Marine Corps Warfighting Lab, 3-5 February 1999.

Jackson, Timothy J., Maj, USMC. Capable Warrior War Game – 3, Assessment. Quantico, VA: Wargaming Division, Marine Corps Warfighting Lab, 12-15 May 1999.

Kipp, Jacob W. *Conventional Force Modernization and the Asymmetries of Military Doctrine: Historical Reflections on AirLand Battle and the Operational Maneuver Group.* Fort Leavenworth, Kansas, 1986.

Office of Naval Research. "MEFFV Variant Definition." Unpublished Presentation Prepared for NSWC – Carderock by Booz-Allen & Hamilton, Inc., May 2001.

Sauer, J. Scot, Maj, USMC. *Fires War Game Executive Summary*. Quantico, VA: Wargaming Division, Marine Corps Warfighting Lab, 21-22 May 2001.

Shumaker, Bradley H. *The Marriage of Deep Maneuver and Marine Light Armored Reconnaissance*. MMS Thesis. Quantico, VA: Marine Corps University Command and Staff College, 1998.

Spinney, Franklin C. *Interference – Interception – Isolation: An Inquiry into the Moral, Mental, and Material Effects of Deep Penetration Operations*. (Working Paper in Progress), March 1985.

MANUALS

Chairman of the Joint Chiefs of Staff *Manual (CJCSM) 3500.04B. Universal Joint Task List,* Version 4.0, 1 October 1999.

Field Manual (FM) 100-5. Operations. Washington, DC: Headquarters, Department of the Army. 14 June 1993.

Joint Chiefs of Staff, *Joint Publication 1-02, Department of Defense Dictionary of Military and Associated Terms*, Washington, DC: GPO, 12 April 2001 (As Amended Through 15 October 2001.

Joint Chiefs of Staff, *Joint Publication 3-0, Doctrine for Joint Operations*, Washington, DC: GPO, 10 September 2001.

Marine Corps Doctrinal Publication (MCDP) 1. Warfighting. Washington, DC: Headquarters, United States Marine Corps, 1997.

Marine Corps Doctrinal Publication (MCDP) 1-2. Campaigning. Washington, DC: Headquarters, United States Marine Corps, 1997.

Marine Corps Doctrinal Publication (MCDP) 2. Intelligence. Washington, DC: Headquarters, United States Marine Corps, 1997.

Marine Corps Doctrinal Publication (MCDP) 3. Expeditionary Operations. Washington, DC: Headquarters, United States Marine Corps, 1998.

Marine Corps Doctrinal Publication (MCDP) 4. Logistics. Washington, DC: Headquarters, United States Marine Corps, 1997.

Marine Corps Doctrinal Publication (MCDP) 6. Command and Control. Washington, DC: Headquarters, United States Marine Corps, 1996.

SOFTWARE

NWSC Caderock and Booz-Allen, Inc. Unpatented Conceptual Sketch Software for MEFFV Program Office, 2001.